

UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF NEW JERSEY

RAJESH KUMAR,)	
)	
Plaintiff,)	
)	Case No. 2:12-cv-06870-KSH-CLW
v.)	
)	EXPERT DECLARATION
THE INSTITUTE OF ELECTRICAL))	OF J. KENNETH SALISBURY JR.
AND ELECTRONICS ENGINEERS,)))	IN SUPPORT OF PLAINTIFF'S
INC.,))	MOTION FOR SUMMARY
Defendant.))	JUDGMENT
_____))	

I, J. Kenneth Salisbury Jr., declare as follows:

1. I have been retained as an expert witness in this case by attorneys for Plaintiff Rajesh Kumar. I have been asked to evaluate certain issues that Plaintiff Kumar has raised in his Motion for Summary Judgment, and to assist the Court in understanding the technology underlying the publications at issue in this matter.

2. I previously have been disclosed as an expert witness in this matter, and issued an expert report on September 13, 2013 and a rebuttal expert report on October 31, 2013. I was deposed by the Defendant ("IEEE") during discovery.

3. As part of my engagement in this matter, I reviewed Dr. Kumar's doctoral thesis entitled, "An Augmented Steady Hand System for Precise Micromanipulation," published in April 2001 (referred to here as the "Thesis"). I also reviewed an article entitled "Task Modeling And Specification for Modular

Sensory Based Human-Machine Cooperative Systems,” authored by D. Kragic and G.D. Hager and published in the proceedings of the 2003 IEEE/RSJ International Conference on Intelligent Robots and Systems by The Institute of Electrical and Electronics Engineers, Inc. (referred to here as the “IEEE Article”).

4. In my opinion, as more completely discussed below, (a) the Thesis is an original work that creatively describes and addresses the goal of enhancing human surgical dexterity with a robotic assistant and the creation of a language to communicate to the robot how to assist the surgeon, and (b) IEEE Article appears to be derived from the Thesis and contains expression that copies and is substantially similar to that contained in the Thesis.

QUALIFICATIONS

5. I am advised that my full Curriculum Vitae, including a list of my publications and prior expert engagements, is on file with the Court as part of the Joint Proposed Pretrial Order. The following is a summary of my qualifications that are particularly relevant to this declaration.

6. I am a Professor (Research) at Stanford University, with joint appointments in Computer Science and Surgery, as well as a courtesy appointment in Mechanical Engineering. I have worked in the field of robotics for over 30 years. After receiving my Ph.D. from Stanford in 1982 in Mechanical Engineering (Design Division), I spent approximately 15 years as a researcher at the

Massachusetts Institute of Technology in the Artificial Intelligence Laboratory and in MIT's Mechanical Engineering Department. Beginning in 1997, I spent four years as Fellow and Scientific Advisor at Intuitive Surgical, Inc. In 1999, I moved to Stanford University, where I have held a number of faculty positions.

7. My academic focus has been in the fields of robotic hands and arms, haptics, robotically assisted surgery, and personal robotics. I am particularly interested in the control and sensing of physical interactions that occur during manipulation, including the manipulation of real and virtual objects and the creation of methods to permit compact encoding of how things feel. For example, I have developed robot hands that can defuse bombs and do gall bladder surgery.

8. I am well-versed in and fully understand the research disclosed in the Thesis and the IEEE Article. My research has included work on surgical simulation and personal and medical robotics. In the past, I have worked to solve a problem similar to the robotic cannulation task discussed in the Thesis, albeit in a physically more course context. That work was discussed in a paper published by IEEE (Salisbury, J.K., "Active Stiffness Control of a Manipulator in Cartesian Coordinates," 19th IEEE Conference on Decision and Control, Albuquerque, NM, Dec 1980, pp. 83-88.) While that work did not operate with the benefit of the robust and modular approach developed by Dr. Kumar, it did introduce me to the issues raised by attempting to satisfy multiple task constraints, creating robot

control methods, and sensing and simple decision making. My more recent work in this area includes instructing a robot to autonomously leave my lab, purchase a cup of coffee on a different floor, return, and deliver it to me. The graph that encoded this “coffee-bot” task has roots in the work described in Dr. Kumar’s Thesis.

9. In the course of my work in this matter, I have reviewed the Thesis and IEEE Article, as well as the following material: the Complaint in this lawsuit; IEEE’s memorandum of law in support of its motion to dismiss Dr. Kumar’s complaint; Dr. Kumar’s memorandum in opposition to the motion to dismiss; portions of Dr. Hager’s deposition in this lawsuit; and the September 17, 2013, opinion letter of IEEE’s retained ophthalmology expert Dr. Thomas R. Friberg.

BACKGROUND ON ROBOTICS

10. One of the most difficult problems to solve in robotics is finding a way to explain to a robot how to do the desired task. Implicit in explaining to a robot how to perform a task is the need for low level “primitives,” or basic computer program instructions, that are robust (meaning that their behaviors are predictable, even in the presence of inaccurate sensor information or poor actuators) and that can be combined to create higher level functionalities. Early robots simply followed predefined trajectories to perform non-contact tasks, such

as spray-painting and welding. (For an example, see Scheinman's Stanford Arm, <http://infolab.stanford.edu/pub/voy/museum/pictures/display/1-Robot.htm>).

11. Programming robots to perform tasks involving contact and the related physics of interaction is more difficult. Robots developed in the 1960s and 1970s used simple commands, instructing a robot to, for example, "move to location A, in three seconds," or "stop if motor is overloaded." These first simple primitives could be combined to perform relatively straightforward tasks such as painting, packing, and simple assembly. With time these combinations of primitives became encapsulated as new, higher-level primitives.

12. This process of making new, more capable primitives from simpler low-level ones is a theme that continues to develop in robotics, enabling more sophisticated tasks to be performed. For example, the robot that bought me a cup of coffee utilized dozens of layers of primitives, each built from lower level primitives. (Pratkanis, A, "An Autonomous Coffee Run with a Mobile Manipulator," ICRA 2013 Karlsruhe, May 6-10, 2013.)

13. As robotics develops more cooperative activity between humans and robots, researchers are continuing to find ways to explain to increasingly smart and capable robot assistants what we intend them to do. Especially in robotically assisted surgery, the challenge of representing how to perform very precise and exacting tasks is especially important to advancing the field.

DR. KUMAR'S THESIS

14. Dr. Kumar's Thesis describes the use of such higher level primitives. More specifically, the Thesis addresses two linked problems in the field of "Assistive Robots" (or Human-Machine Cooperative Systems, as the IEEE Article calls it). One is how to control the "Steady Hand" robot developed at Johns Hopkins University in prior research. The Steady Hand allows a doctor to hold the handle of a surgical instrument, and with the assistance of the robot, control very small motions and force exertions at the instruments, providing the type of steadying and interaction scaling as might be needed in delicate eye micro-surgery.

15. The second portion of the Thesis introduces a "task graph" to encode a higher level task strategy using lower level primitives (e.g. "move to A," "Report a Contact Event," "Constrain My Motion to a Plane," etc.) as elements of the graph. This portion of the Thesis teaches how to "explain" to the robot how to perform a task that is composed of a sequence of states or action, and event-triggered transitions.

16. Figure 5.13 of the Thesis clearly describes this strategy. It shows states (or actions) in ellipses and the possible transitions from one state to another as connecting arrowed arcs. The topology (organization of connections) of this graph and the selection of connections (transitions) between states embodies a plan

for executing the higher level task of retinal vein cannulation, in the context of the experimental proof of concept described in the Thesis.

17. There are many other ways this retinal vein cannulation task could have been programmed. Additional states could have been added; states could have been combined; and each action could have been further decomposed into narrower sub-states. In my opinion, Figure 5.13 and the accompanying discussion reflect substantial creative thought described in an innovative manner. They convey in an intuitively understandable way the strategy being constructed to accomplish and encode a particular task. The task graph intrinsically lends itself to building bigger and more capable “task units.” It is visually appealing with concise description of the constituent elements.

18. This portion of the Thesis reflects Dr. Kumar’s creative insights in several respects. Constructing the graph requires choosing the various states that task execution must progress through in order to complete the task. It also requires choosing the appropriate level of abstraction. Each state signifies a particular primitive, performing a particular task in which certain events may occur, or cause the system to move to a new state. The construction of the state and transition elements shown in the Thesis is very modular and incrementally improvable. New event detection, contingences and other control flow actors can be added at will to improve the system.

19. Based on my experience in this field, it is my opinion the task graph and accompanying discussions in the Thesis reflect a creative and original manner of programming a robot to perform a complex surgical procedure, expressed in an innovative manner. The ability to take a complex and ill-designed language problem – how to speak to a robot – and break it down to a vocabulary, relatively simple but sufficiently expressive to enable building highly capable task graph robot instructions, is a significant accomplishment. Again, there are many other ways this strategy could have been expressed.

20. I understand Defendant has argued in this lawsuit that task graphs are commonly used in the field of robotics. While such figures may appear in the literature, I am not aware of previous task graphs that are used in the manner Dr. Kumar uses them in his Thesis – that is, as a high level expression of how to program a semi-autonomous robot's motion and sensing capabilities in coordination with human input. Graphically showing this sequence of actions and events, in a context that allows a human and robot to take shared and alternating responsibility for performing the task, is an original contribution of Dr. Kumar's.

21. It is important to note that the Thesis does not (and does not claim to) break new ground on the subject of how retinal vein cannulation is performed by a surgeon. Again, Dr. Kumar's key insights involve describing to a steady-hand robot how to perform and augment the performance of a specified task. The Thesis

is about robotics, not a medical procedure. Though Dr. Kumar's task graph representation is applied to a cannulation experiment, the importance of the task graph (and the Thesis generally) lies not in its mere naming of some of the steps of the cannulation task, but rather in its graphical expression of the sequence of actions and events that will occur to allow cooperative performance of a complex, robot-augmented task in a manner that is understandable and extendable to many human/robot cooperative applications.

22. The Thesis is creative and original in other respects as well. As described in the Thesis itself (Section 2.3, pp. 19-20) the Thesis' contributions include implementation of a framework for task specification; modeling and analysis of suitable tasks; comparative performance measurement; and the design and implementation of a modular architecture for robot control. Based on my review of the Thesis and my familiarity with the development of the field of robotics as noted above, I believe Section 2.3 accurately reflects the innovative and original contributions of Thesis overall.

23. It should further be noted that these contributions presumably would have been considered original in the eyes of Dr. Kumar's thesis advisor, as well as his reading and examination committee. A Ph.D. should not be awarded unless the candidate makes a new contribution to knowledge, as was attested to by Kumar's examiners.

THE IEEE ARTICLE

24. Like the Thesis, the IEEE Article addresses control of the “Steady Hand” robot, and encoding of higher level task strategy using lower level primitives. Like the Thesis, the IEEE Article uses a “task graph” to describe this task strategy.

25. In my opinion, the IEEE Article is substantially similar to and appears derived from the Thesis. The particular similarities are noted below.

26. The IEEE Article mirrors, first, the overall form, content, organization and conclusions of the Thesis, albeit in abridged form. The article essentially abridges the Thesis and its key conclusions, minus the experimental validation performed by Dr. Kumar.

27. The most obvious similarity in the expression contained in the two works is the IEEE Article’s use of a task graph (Figure 1) that is nearly identical to the graphical depiction of Kumar's task graph discussed above. The task graph is the core of both works – the blueprint for the system architecture and visual depiction of the code generated to operate the robot. The version in the IEEE Article rotates the image and makes a few other changes, but these are cosmetic. The figures express the same tasks, in the same order, for the same purpose.

28. To appreciate the significance of this similarity requires some understanding of what is contained in a task graph. A task graph is a visual

representation of “states” to accomplish and “events” that might cause movement to another state. A “state” can be nearly anything, from pressing a button, to standing on one leg, to driving at 30 miles per hour. An “event” requires attention and possibly movement to a different state. With two simple logic elements, a state and an event detector, tremendously complex systems can be (recursively) created, but in a systematic way that allows one to view it from many different levels of abstraction.

29. To formalize and demonstrate by example the use of a task graph for direction of a robot performance is, again, a significant accomplishment of Kumar’s Thesis. This resulted from his investigation of graph properties, as set out in Section 4.3 of the Thesis, which yields insight pertaining to the feasibility of graph-based task descriptions. Thus, as noted above, Figure 5.13 reflects the Thesis’ unique application of task graphs and related terminology to describe state-machines in steady hand manipulation. Figure 1 of the IEEE Article is strikingly similar: it depicts the same task, decomposed to the same level of abstraction, using the same symbols and same visual depiction.

30. There are differences between the task graph in the Thesis and the one in the IEEE Article, but they are superficial. For example, the “contact” task is shown differently in the two works, and both depict error transitions in slightly different ways. These differences do not undermine my conclusion that the IEEE

Article version copied the creative and original expression found in the Thesis version – namely, the unique manner in which it shows graphically the sequence of actions occurring in this complex, robot-augmented task, in a modular and extendable manner.

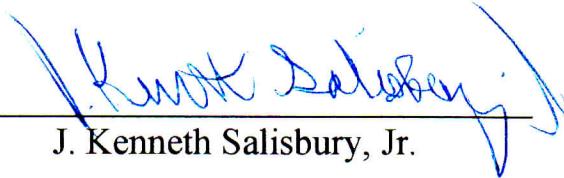
31. Beyond the task graphs, the IEEE paper also appears to me to be substantially similar to and derivative of Kumar's thesis. For example, Section VIII of the IEEE Article (“Example Scenario”) expresses in XML language the same steps shown visually by the task graph, and thus amounts to the same computer program that the Thesis describes in a different language.

32. Section IV of the IEEE Kragic Article (“Basic Primitives”) likewise contains routines and primitives taken from the Thesis. The framework, task elements and terminology that the IEEE Article uses to express these instructions are all functionally the same as is found in the Thesis.

33. In my opinion, the IEEE Article offers no insight into task-level programming of cooperative human-robot systems that is not also contained in the Thesis.

I declare under penalty of perjury under the laws of the state of the United States of America that the foregoing is true and correct.

Executed at Mountain View, California, this 13th day of February, 2015.



J. Kenneth Salisbury, Jr.